Comparison Of Reproductive Traits In Hatchery And NOR Cedar River Sockeye Used As Broodstock At The Landsburg Hatchery In:

2006 & 2007

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Synopsis Of Results 2006

1) Eight thousand eight hundred and twenty-nine sockeye were spawned at the Landsburg Hatchery over a nine-week period in 2006. Biological information, including POH lengths, age-at-maturity, fecundity, relative fecundity, egg weight, and reproductive effort were collected on 2,296 fish or 26% of the broodstock. Approximately 91% of the fish sampled had matured at age 4, 8.7% were age 5 and less than 0.3 % had reached maturation at ages 3 or 6.

2) Approximately 54% of the fish sampled were of hatchery origin. The percentage of hatchery fish remained relatively constant across the nine week spawning season.

3) ANOVAs using POH data collected from hatchery origin fish indicated that time of release as a fry did not affect size at maturity in 5-yr-old males and females. Moreover, time of release did not affect size in 4-yr-old males and females that were released as fed or unfed fry in a feeding experiment. However, 4-yr-old males and females that had been released as unfed fry during the early release period that were not part of the feeding experiment were larger at maturation than 4-yr-old males and females that were released as unfed fry during the middle and late periods.

4) No difference was seen in the body sizes of 4-yr-old males that had been released as fed or unfed fry during the feeding experiment. The same result occurred for 4-yr-old females. When POH lengths of NOR and hatchery origin fish were compared it was found that: a) 4-yr-old males produced from early unfed hatchery fry and NORs were larger than hatchery adults produced from unfed fry released during the middle and late periods, b) 4-yr-old females produced from fed fry and NORs were larger than adults originating from unfed fry that had been released during the middle and late periods, c) 5-yr-old male NORs were larger than 5-yr-old hatchery males, and d) that 5-yr-old NOR females were larger than 5-yr-old hatchery origin females

5) Age of maturation in hatchery origin males and females was not affected by when they were released as fry.

6) Age of maturation in NOR and hatchery origin males and females differed. There was a slightly higher incidence of 4-yr-olds in both male and female hatchery fish and a corresponding decrease in 5-yr-old hatchery fish when compared to NORs returning to spawn in 2006.

7) When within a spawning season a hatchery fish became physiologically mature was affected by when its parents reached maturation. For instance, hatchery fish that were spawned in the early portion of their spawning season produced male and female adult offspring that were spawned early in their spawning seasons. The same trend held up for fish that were spawned in the middle and late periods, their offspring also tended to reach maturation at the same relative time as their parents.

8) Positive relationships were detected between female body weight and fecundity. Between 40 to 50% of the variation in egg number could be explained by female weight. NOR and hatchery females had the same body size x fecundity relationships (slopes and y-

intercepts were comparable). Female age, but not origin, affected mean fecundity values. Five-yr-old females had on average 726 more eggs than 4-yr-old fish.

9) Neither female age nor origin affected relative fecundity which averaged 1,878 eggs per kilogram of body weight.

10) No relationship was observed between female body weight and water hardened egg weight except in 4-yr-old NORs. In this case only 11% of the variation associated with egg weight could be explained by female body weight. Neither age at maturity nor origin affected mean egg weights in 4- and 5-yr-old NOR (4-yr-olds = 107.8 mg; 5-yr-olds 113.0 mg) and hatchery (4-yr-olds 105.8 mg; 5-yr-old 106.7 mg) females.

11) Neither female age nor origin affected reproductive effort in females which averaged 19.99%.

12) Minor differences in age composition and size at age occurred between NOR and hatchery origin sockeye. However, in general the reproductive traits of NOR and hatchery origin sockeye used as broodstock in 2006 were very similar to one another.

Synopsis Of Results 2007

1) One-thousand six-hundred and sixty-four sockeye were spawned at the Landsburg Hatchery over a nine week period in 2007. Biological information, including POH lengths, age-at-maturity, fecundity, relative fecundity, egg weight, and reproductive effort were collected on 632 fish or 38% of the broodstock. Approximately 96% of the fish sampled in 2007 were age 5 fish. No 4-yr-old hatchery fish were sampled and only 3.3% of the NORs examined matured at age 4. No 6-yr-old fish were seen, however, about 2% of the hatchery fish examined had matured at age 3. The absence of 4-yr-old NORs and hatchery origin fish suggest that a total collapse of the 2003 broodyear has occurred.

2) Approximately 40% of the fish sampled were of hatchery origin. The percentage of hatchery fish remained relatively constant across the nine week spawning period.

3) ANOVAs using POH data collected from hatchery origin fish indicated that time of release as an unfed fry affected length at maturity in 5-yr-old males originating from fry that were not part of a 2003 feeding experiment at the hatchery. Individuals released as unfed fry during the early period were larger than those liberated during the late period. Time of release did not affect POH length in 5-yr-old females that originated from unfed fry which were not included in the feeding experiment.

4) Male 5-yr-olds produced from fed and unfed fry used in the feeding experiment had similar POH lengths at maturity. Five-yr-old females released as fed and unfed fry during the feeding experiment also had similar POH lengths at maturity.

5) Five-yr-old hatchery and NOR females had similar POH lengths. Five-yr-old hatchery males originating from fry released during the early period that were not part of the feeding experiment had greater POH lengths than NORs and all other hatchery origin 5-yr-old males.

6) Time of fry release (early, middle, or late) had no affect on age of maturation in hatchery males and females

7) The incidence of 5-yr-old fish in hatchery and NOR males and females was comparable.

8) When within a spawning season a hatchery fish became physiologically ready to spawn was affected by when its parents reached maturation. Hatchery fish that were spawned in the early part of the spawning season produced male and female offspring that spawned early in their spawning seasons. The same trend held up for fish spawned in the middle and late periods, their offspring also reached maturation at the same relative time as their parents.

9) Positive relationships were detected between female body weight and fecundity. Between 40 to 50% of the variation in fecundity could be explained by female weight. NOR and hatchery females had the same body size x fecundity relationships (slopes and y-intercepts were comparable). Female age, but not origin affected mean fecundity. Five-year old NOR females had on average 861 more eggs than 4-yr-old NOR females.

10) Significant negative linear relationships between female weight and relative fecundity (eggs produced per kilogram of body weight) were found in NOR and hatchery origin females. The slopes and y-intercepts in these regressions were similar and the mean relative fecundity values of 5-yr-old hatchery and NORs were comparable and averaged 1,727 eggs per kilogram.

11) Positive relationships between female weight and egg weight were found in 5-yr-old NORs and hatchery females; female weight could explain about 16% of the variation in egg weight. The slopes and y-intercepts of these two regressions were similar and no difference in mean egg weight was found between 5-yr-old NOR and hatchery females (NOR, 111.2 mg vs. hatchery, 111.7 mg). Four-yr-old NOR females had significantly smaller eggs (98 mg) than the five-yr-old fish.

12) Female age and origin did not affect reproductive effort; all females had reproductive effort values that averaged 19%.

13) In general, the reproductive traits of NOR and hatchery origin sockeye used as broodstock in 2007 were quite similar to one another.

Introduction

In 1991, an interim sockeye salmon hatchery was established on the Cedar River just below the Landsburg Dam at RK 36. Initially a goal of 2 to 3 million eggs was established for the hatchery. This value was based on the assumption that the program would contribute 30 to 45 thousand adults to the Cedar River, which would be enough to perpetuate the population in case flooding or other factors impacted natural production. In 1991 and 1992 broodstock were obtained by seining portions of the Cedar River. This proved to be very labor intensive and consequently, in 1993 a temporary weir was placed at RK 10. It was used to collect broodstock from 1993 through 2007. Beginning in 2008 a new weir was installed at ~ RK 1.2. The new weir is designed to tolerate higher flows than the one previously used. This means that later maturing fish can now be collected and used by the hatchery. Moreover, its placement in the lower part of the Cedar River also facilitates the collection of sockeye returning to all parts of the river. The placement of the original weir only allowed fish spawning in the upper two thirds of the river to be used as potential broodstock. Thus, the new weir's placement and fishing capacity will likely improve how broodstock are collected.

Two increases in the hatchery's egg take goal have occurred. One happened in 1993, the first year that the older weir was employed. At this time the goal was raised to 8 million eggs. In 1996, the goal was increased to its current 16 million egg level. From the hatchery's inception, planned water temperature alterations during the last half of the incubation period have been used to induce bar codes (Volk et al. 2005) into the otoliths of every sockeye produced by the facility. These marks are used to identify the broodyear, release location, and release date of every hatchery fish. Most of the fish produced by the hatchery are released as unfed fry. Beginning in 2000, however, some fish were fed for about two weeks prior to being liberated. To evaluate the effects of that strategy, thermal marks were created that also allowed the rearing history of a fish to be identified. Although 100% of the hatchery fish are thermally marked there is no way to use external characteristics to identify hatchery and natural origin recruit (NOR) sockeye. Instead, otoliths must be extracted and decoded to the determine fish origins. Therefore, starting in 1995 NOR and hatchery origin sockeye have supplied gametes to the hatchery.

Hatcheries that use both NOR and hatchery-origin fish as broodstock have been referred to as "integrated programs". Recently the Hatchery Scientific Review Group (HSRG) has recommended that 50% or less of the broodstock used in an integrated hatchery program should be of hatchery origin. The rationale behind the HSRG's proposal is the belief that inadvertent domestication caused by hatchery conditions can alter reproductive traits in hatchery salmonids. Two possible mechanisms may cause domestication to occur in salmonids while they are exposed to hatchery conditions. The first is the relaxation of natural selection pressures. Fish that would normally perish under natural conditions because of the possession of unsuitable traits can survive in a more benign hatchery environment. If these traits have a genetic basis, they may become established in a population. Second, unlike the natural environment which is often quite variable, hatcheries tend to possess consistent environmental conditions. Under this circumstance, selection for genetic traits that adapt fish to artificial culture is likely to occur. Finally, characteristics that are favored in a hatchery environment may negatively impact individuals when they reside in natural environments. Hence, the combination of relaxation and directed selection may create fish well adapted for artificial culture but poorly suited for natural conditions (Einum and Fleming 1997; McGinnity et al. 1997; Fleming et al. 2000; Einum and Fleming 2001; Dannewitz et al. 2004; Knudsen et al. 2008). The potential for hatchery fish to become domesticated led the HSRG to develop their 50% rule, which is designed to prevent population-specific traits from being significantly altered by artificial culture. Often salmon hatcheries use hatchery fish as broodstock from one generation to the next. When this happens shifts in traits may occur. By inserting NORs into a hatchery's broodstock the rate at which traits change will be reduced and how they are expressed should resemble that found in the natural population.

Beginning in 1996, sockeye broodstock used at the Landsburg Hatchery have been sampled to determine their origin, age, and length. Comparisons between hatchery and NOR sockeye based on these traits have been made (Fresh et al. 2003). Although size and age maturity are important, other traits potentially related to genetic fitness should also be monitored to fully evaluate whether the hatchery program has affected the Cedar River sockeye population. In recognition of this need, Seattle Public Utilities provided WDFW with support to collect and compare information on the size, maturation timing, fecundity, relative fecundity, egg sizes and reproductive effort values of NOR and hatchery-origin fish used as broodstock at the Landsburg Hatchery. These comparisons were begun in 2005 and have continued to the present date. In this document, we present the results of analyses that compared reproductive traits in hatchery and NOR sockeye used as broodstock in 2006 and 2007.

Methods

Collection, Holding, and Sampling of Broodstock

In 2006 and 2007 a portable weir was installed at RK 10 and was used to collect sockeye adults for broodstock as they migrated up the Cedar River. Captured fish were transported to the Landsburg Hatchery (RK 36) and held in circular tanks until they reached maturity. Spawning at the hatchery occurred once or twice a week from September to mid-November in 2006 and from late September to late November in 2007. At least 20% of the fish used as broodstock were sampled. Sampled fish were chosen in a systematic manner, for example on a given spawning date, data were obtained on every fifth male and fifth female spawned. This approach was used to create a representative sample. Data were collected on the fish after they had been killed.

Data Collected On Males

The length of each male was determined by using post-orbital to hypural plate measurements (POH). As male salmon mature significant lengthening of their heads caused by kype and lower jaw growth will occur. This growth affects standard length measurements like total and fork lengths. POH length on the other hand is not influenced by such changes and therefore it is a preferred metric of fish length in maturing salmonids.

Both saggital otoliths were removed from each male and placed into labeled vials containing 100% ethanol. Otoliths were used to assign an age to each fish by counting the number of annuli seen on their external surface. Because 100% of the fish produced from the Landsburg Hatchery have thermal codes in their otoliths these structures were also examined to determine if a male possessed a thermal mark. Thermal marks were detected by using methods described by Volk et al. (1999) and Volk et al. (2005). Briefly, saggitae otoliths were cast into resin blocks and individual specimens were sectioned and polished by using lap wheels that removed material until the primordial core of an otolith was exposed. Otoliths were then examined using a compound microscope under 100 or 200x and the presence or absence of a thermal mark was ascertained. If a mark was seen, its specific pattern was recorded. These patterns identified the rearing and release treatment the fish received and also the brood year that it originated from. Two readers independently examined each otolith and decode results were compared. If differences occurred, the specimen was retrieved and re-inspected until agreement was reached. Length, age, and origin data on each male were entered into an electronic database to facilitate later statistical analyses.

Data Collected On Females

POH lengths, age, and origin information on females were obtained in the same manner as that used for males. Body weights were obtained on 174 (2006) and 257 (2007) randomly chosen females. Before being weighed, surface water, mucus, and other debris were wiped from each female by using absorbent paper toweling. The fish were then placed on an electronic balance and weighed to the nearest gram. After being weighed the females were artificially spawned. The eggs and ovarian fluid obtained from each fish were placed into individual 7.6 *l* plastic buckets. The total egg mass weight of each female was determined by separating her eggs from any ovarian fluid she may have had. This was accomplished by pouring her eggs and ovarian fluid into a plastic colander. The eggs sans ovarian fluid were then weighed to the nearest 0.1 gram on an electronic balance. Egg mass weight along with a parameter referred to as average green egg weight were used to estimate the fecundity of each sampled female. Mean green egg weight estimates were determined by collecting two egg samples that weighed between 5 and 10 g each from the egg mass of each sampled female. The egg samples were weighed to the nearest 0.01 gram on an electronic balance. After weighing, the eggs were counted twice. An average green egg weight for each sample was calculated by dividing the weight of the egg sample by the number of eggs it contained. Mean egg weights from the two samples were averaged and fecundity was estimated by dividing a female's egg mass weight by the overall mean weight of her green eggs.

The average water hardened egg weight for each sampled female was also determined by taking five eggs from her egg mass and placing them into a labeled, 20 ml capacity, polyethylene vial partially filled with water. The eggs were allowed to absorb water for 24 hrs while they were kept on ice or refrigerated. After water absorption was completed, each egg was blotted dry in a standardized fashion prior to being individually weighed to the nearest mg (0.001 g) on an electronic balance. These values were summed and divided by five to generate an average water hardened egg weight.

Two other parameters, reproductive effort and relative fecundity, were also calculated. Reproductive effort or the gonadosomatic index of a female was estimated by dividing the female's egg mass weight by her body weight. Relative fecundity, or the number of eggs produced per kilogram of body weight, was calculated by dividing a female's fecundity estimate by her body weight in kilograms.

Analytical Approach

Our assessments of reproductive traits in the fish used as broodstock at the Landsburg Hatchery had two objectives. The first was to compare on a yearly basis, age and size at maturity, fecundity, relative fecundity, egg size, and reproductive effort in NOR and hatchery-origin sockeye. The second is to start compiling information on these traits so that long-term trend analyses can be performed to see if hatchery-origin fish diverge from NOR sockeye as the hatchery program continues.

Sockeye produced by the Landsburg Hatchery were separated into distinct groups based on their rearing and release histories. This was done because the effects of different hatchery treatments on the adult traits being measured and compared were not known. Two general types of hatchery fish were created; one was referred to as "*rearing type*" while the other was called "*release type*." Three rearing types, fed, controls, and unfed were identified. The fed and control groups represent fry that were used in a feeding experiment conducted at the hatchery. In this experiment groups of fry were fed for about two weeks before being released simultaneously with unfed control fry at the mouth of the Cedar River. Most sockeye released from the Landsburg Hatchery are released as unfed fry and the unfed rearing group represents all releases that were not used as controls in the feeding experiment.

Two factors can be used to define release type. One of these is based on where in the Cedar River hatchery fry are released (upper, middle, or lower portions of the river). The other considers when fry are released (early, middle, or late segments of the hatchery release schedule). When these two factors are combined a total of nine possible release types can be created (e.g. upper river-early release; upper river-middle release; upper river-late release; and so on). However, in the analyses that follow, location of release was not considered to be an important variable because where a fish was released within the Cedar River was not expected to affect traits at the adult stage. Consequently, release type was restricted to when a fry was released. Three release types were used, early, middle, and late. As alluded to above, fish classified as early would have been liberated during the first third of the hatchery fry release period. Similarly, middle and late fish would have been released during the middle and last third of a hatchery release period. Comparable information on when a NOR adult may have entered Lake Washington at the fry stage to rear was not available. Consequently NORs were simply pooled into groups based upon their age and gender.

Comparing Lengths Of NOR and hatchery-origin adults

In these comparisons, age and gender were held constant and the same multi-step procedure was followed for both sexes. First, length data (POH values) on hatchery origin fish were sorted by gender, age of maturation, and rearing type. Next one-way ANOVAs were performed to see if release time affected POH lengths at maturity within hatchery fish that were the same age, gender, and were from the same rearing type (feds, controls, or unfed). Subsequent ANOVAs were performed to determine if release type affected size at maturation. ANOVA was also used to compare hatchery adults originating from different release types to NORs. As in previous analyses, the age and gender of the hatchery and NOR fish being compared were the same. Finally to examine the effect of age at maturation on size, ANOVAs were performed where only gender was held constant. This allowed us to simultaneously evaluate the effect of age and origin (NOR and hatchery rearing types) on size at maturation within the same gender. Ancillary ANOVAs were performed to assess whether adults produced from the fed and control treatments in the feeding experiment had similar body sizes at maturity. In these ANOVAs gender and age were once again held constant.

Comparing Age of Maturation in NOR and hatchery-origin adults

Two series of Chi-Square analyses were performed to assess whether NOR and hatchery-origin sockeye had matured at similar ages. The first set of chi-squares evaluated whether time of release affected age of maturation in hatchery fish. The second set consisted of a series of 2 x 2 contingency chi-square tests (Zar 1999) that evaluated whether NOR and hatchery-origin fish having the same gender matured at similar ages.

Evaluating The Relationship Between Release Type and Maturation Timing In Hatchery-Origin Sockeye

Two factors made it possible to see if the maturation timing of hatchery broodstock affected when their offspring reached maturity. First, thermal otolith marks were developed to enable us to identify when a hatchery fish had been released as a fry (i.e. during the early, middle, or late portion of the hatchery fry release period). Second, the use of incubation water with a relatively constant temperature at the hatchery means that fry from parents that are spawned early will produce fry that are released early. Kolmogorov-Smirnov two-sample tests (Siegel 1956) were employed to assess whether parental maturation timing affected when their offspring would become ripe. We equated maturation time for a fish with the day it was artificially spawned. In these analyses gender was kept separate but maturation data on 4- and 5-yr-old fish was combined. Six comparisons were made, early vs. late, early vs. middle and late vs. middle in males and females. In addition, the affect of gender on maturation timing was evaluated by comparing when males and females originating from the same fry release were artificially spawned.

<u>Comparing Fecundity and Relative Fecundity in Hatchery and NOR Females</u>

Fecundity Comparisons. Linear regressions were used to determine if relationships existed between female body weight and fecundity (total egg number) in hatchery and NOR females. When possible separate regressions were performed on data collected from 4- and 5-yr-old hatchery females and for 4- and 5-yr-old NOR females. The natural log transformation was used on both the independent (body weight in grams) and dependent variable (egg number) in these analyses to normalize the data. Methods described by Zar (1974) were then employed to see if the slopes and y-intercepts of the regression models were dissimilar. When the null hypotheses of equivalent slopes and y-intercepts could not be rejected, regression models predicting fecundity based on body weight from all the females sampled were performed.

Relative Fecundity Comparisons. Similar linear regressions were performed on the relative fecundity data to see if a relationship existed between the body weight (ln) of a female and the number of eggs she produced per kilogram of body weight (ln). As in the fecundity analyses, tests described by Zar (1974) were used to determine if the slopes and y-intercepts of the regressions were dissimilar. Separate regressions were performed on 4- and 5-yr-old hatchery and NOR females.

<u>Comparing Egg Size in NOR and Hatchery Females</u>

Regression analyses were again used to examine the relationship between female size and egg weight after both of these variables had been normalized with the natural log transformation. Separate regressions were performed for 4- and 5 yr-old hatchery and NOR females. When these regressions were significant their slopes and y-intercepts were compared using the method described above. Additionally, a two-way ANOVA that compared the mean egg sizes of 4- and 5-yr-old NOR and hatchery females was performed to see if size differences existed in their eggs.

<u>Comparing Reproductive Effort in NOR and Hatchery Females</u>

During normal hatchery operations, a few females will expel eggs while being held prior to spawning or will lose eggs during the spawning process. In general, semelparous female salmonids will allocate about 17 to 22% of their total body weight to eggs. This percentage has been referred to as reproductive effort. We examined the reproductive effort (RE) values that were calculated on the females we sampled and excluded those that were less than 17% from further analysis. The remaining RE values were used in a two-way ANOVA with fixed factors of age (4 or 5) and origin (hatchery or NOR) that evaluated whether differences in RE could be linked to age at maturity or female origin. Prior to performing the analysis, all the RE values were normalized by using the arcsine square root transformation.

Data Presentation

In this report we present data collected from broodstock that were used at the Landsburg Hatchery in 2006 and 2007. In 2006 we submitted a report to Seattle Public Utilities that compared reproductive traits in hatchery and wild sockeye used at the hatchery in 2005. The tables and information reported here closely resemble those used in our previous report. This was done so that when trend analyses are performed data on the traits being compared can be quickly extracted. To facilitate that further, findings for 2006 and 2007are presented in two separate sections.

Results & Discussion: 2006

Occurrence Of Hatchery Fish In The Broodstock

In 2006, 54% of the sockeye used as broodstock at the Landsburg Hatchery were of hatchery origin. This is just the third time over an eleven year period where the percentage of hatchery fish used as broodstock has exceeded the level recommended by the HSRG (Table 1). Overall the hatchery program appears to be consistently adhering to the broodstock guidelines established by the HSRG. The relatively high abundance of hatchery fish in the 2006 broodstock was unexpected. For example, most of the fish used as broodstock in 2006 originated from the 2002 broodyear, that is, they were 4-yr-olds (*see* below). In 2003, when those fish left the Cedar River and entered Lake Washington as fry, it was estimated that 66% of them were produced by NOR parents while 34% were of hatchery origin (Seiler et al. 2005). If the fish used as broodstock are representative of the entire population, and if hatchery and NOR fry-to-adult survival rates are equivalent, then 34% of the fish used as broodstock in 2006 should have been hatchery origin fish. There appear to be at least three possible explanations for why we saw a greater abundance of hatchery fish in the broodstock than expected. First, the number of NOR fry leaving the Cedar River in 2003 may have been overestimated; second, hatchery fry have achieved higher fry-to-adult survival rates than NOR fry; or third some biases occurred when broodstock were collected. Of the three possibilities, we speculate that the most likely cause is how broodstock were collected. The weir used to collect broodstock was located above some major spawning areas utilized by NOR adults so many NORs never migrated past the weir. Moreover, stream flows curtailed how long it could be effectively fished so NORs returning in late November and December 2006 could not be sampled. In combination the spatial location of the weir and when it was operated may have constrained the types of fish that were available for capture. However, no matter what the cause for the higher than expected presence of hatchery fish in the 2006 broodstock, it is clear that hatchery fry contributed significant numbers of adults to the Cedar River population. What their actual contribution rate may be will require more careful analysis than can be provided here.

Table 1. The occurrence of hatchery origin sockeye in the broodstock used at the Landsburg Hatchery from 1996 through 2006.

	% Of Hatchery Fish Used As Broodstock By Return Year										
Return Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
% Hatchery Fish	4%	12%	35%	45%	46%	38%	60%	54%	32%	33%	54%

Out of the 8,829 sockeye spawned in 2006 at the Landsburg Hatchery, 2,296 (1,146 females and 1,150 males) were sampled over a nine week spawning period. As Table 2 illustrates, 26% of the fish used as broodstock in 2006 were sampled. The age and origin of the fish that were sampled is shown in Table 3. The column labeled "% Within A Type" indicates the percentage of fish that were hatchery or NOR origin that were a given age. For example, 92.98% of all the hatchery males sampled were 4-yr-olds. The column titled "% Within A Sex" indicates the percentage of males, regardless of origin that were a particular age. For instance, in 2006, 89.98% of all males sampled were 4-yr-olds.

In 2006, sockeye were spawned over a nine week period beginning in the week of September 17 – 23 and ending during the week of November 12 - 18. No formal analyses were performed to see if the percentage of hatchery fish used as broodstock changed from one spawning week to the next. However, Table 4, parts A and B and Figure 1 indicate that this percentage remained relatively constant, between 50 to 60% during the eight weeks fish were sampled.

Length Comparisons Between Hatchery and NOR Sockeye Used As Broodstock

Tables 5A and 5B summarize the POH data collected on the 4- and 5-yr-old broodstock that were sampled. Eight ANOVAs were performed using POH data collected on hatchery origin fish to determine if time of release affected size at maturity (Table 6). In these tests, the affects of time of release were examined in fish that were the same age and sex. The first two examined whether size at maturation in 4-yr-old males or females that were used as unfed controls in the feeding experiment had been affected by when they were released as fry. POH lengths in these fish were not affected by time of release ($P = 0.957$ for males; $P = 0.580$ for females). The next two ANOVAs evaluated whether size at maturation in 4-yr-old males or females that were released as fed fry had been influenced by when they were released. Again, when these fish were released as fed fry had no apparent affect on their size at maturation ($P = 0.157$ for males; $P = 0.628$ for females). Two similar ANOVAs were performed on the POH data collected from 4-yr-old males and females that had originated from unfed fry that were not part of the feeding experiment. In this case time of release did have an effect. In males, individuals released during the early period were significantly larger at maturation than those liberated during the middle and late release periods ($P = 0.002$). For females, unfed fry released during the early period were larger than those liberated during the middle period but no size difference appeared to exist between 4-yr-old females released during the middle and late periods. The last two ANOVAs

Table 2. The number of male and female sockeye spawned and sampled per week at the Landsburg Hatchery from September through December 2006.

Spawning Week	No. Of Females	No. Of Males	Total Fish Spawned	Total Fish Sampled	% Sampled By Week	Females Sampled	% By Week	Males Sampled	% By Week
17 - 23 Sep	100	100	200	0	0	0	0.00%	0	0.00%
24 - 30 Sep	509	509	1018	204	20.04%	102	20.04%	102	20.04%
1 - 7 Oct	745	745	1490	186	12.48%	92	12.35%	94	12.62%
8 - 14 Oct	763	763	1526	288	18.87%	150	19.66%	138	18.09%
15 - 21 Oct	853	570	1423	336	23.61%	149	17.47%	187	32.81%
22 - 28 Oct	845	845	1690	500	29.59%	250	29.59%	250	29.59%
29 Oct - 4 Nov	499	359	858	580	67.60%	311	62.32%	269	74.93%
5 - 11 Nov	288	288	576	154	26.74%	68	23.61%	86	29.86%
12 - 18 Nov	24	24	48	48	100.00%	24	100.00%	24	100.00%
19 - 25 Nov									
26 Nov - 2 Dec									
3 - 9 Dec									
Totals	4626	4203	8829	2296	26.01%	1146	24.77%	1150	27.36%

Table 3. The origin, sex, and ages of the sockeye salmon that were sampled at the Landsburg Hatchery in 2006.

Type	Age	n	% Within A Type	% Within A Sex
Hatchery Male	3	1	0.17%	0.09%
	4	556	92.98%	89.98%
	5	39	6.52%	9.76%
	6	2	0.33%	0.17%
Subtotal		598		
NOR Male	3	0	0.00%	0.09%
	4	477	86.73%	89.98%
	5	73	13.27%	9.76%
	6	0	0.00%	0.17%
Subtotal		550		
Grand Total		1148		
Hatchery Female	3	0	0.00%	0.09%
	4	600	95.09%	92.15%
	5	30	4.75%	7.68%
	6	1	0.16%	0.09%
Subtotal		631		
NOR Female	3	1	0.19%	0.09%
	4	456	88.54%	92.15%
	5	58	11.26%	7.68%
	6	0	0.00%	0.09%
Subtotal		515		
Grand Total		1146		

Definitions: % Within a Type = percentage of fish that were a given age within a fish type (e.g. NORs or Hatch) when gender was held constant

% Within a Sex = percentage of fish that were a given age within the same gender (combined NOR and Hatch data)

Table 4A. The occurrence of 3-, 4-, 5-, and 6-yr-old NOR and hatchery origin sockeye males by spawning week in the broodstock used at the Landsburg Hatchery in 2006.

Spawning Week	Type Of Male	No. Of 3's	No. Of 4's	No. Of 5's	No. Of 6's	Totals By Type	Total Males	% Hatchery
17 - 23 Sep	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
24 - 30 Sep	NOR	0	45	5	0	50		
	Hatch	0	48	3	1	52	102	50.98%
1 - 7 Oct	NOR	0	48	6	0	54		
	Hatch	0	36	4	0	40	94	42.55%
8 - 14 Oct	NOR	0	58	10	0	68		
	Hatch	1	66	2	0	69	137	50.36%
15 - 21 Oct	NOR	0	79	9	0	88		
	Hatch	0	90	9	0	99	187	52.94%
22 - 28 Oct	NOR	0	102	14	0	116		
	Hatch	0	126	7	0	133	249	53.41%
29 Oct - 4 Nov	NOR	0	104	22	0	126		
	Hatch	0	132	10	1	143	269	53.16%
5 - 11 Nov	NOR	0	32	3	0	35		
	Hatch	0	49	2	0	51	86	59.30%
12 - 18 Nov	NOR	0	9	4	0	13		
	Hatch	0	9	2	0	11	24	45.83%
19 - 25 Nov	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
26 Nov - 2 Dec	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
3 - 9 Dec	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
TOTALS		1	1033	112	2	1148		52.09%
Summary	NOR	0	477	73	0			550
	Hatch	1	556	39	2			598
	Totals	1	1033	112	2			1148

Table 4B. The occurrence of 3-, 4-, 5-, and 6-yr-old NOR and hatchery origin sockeye females by spawning week in the broodstock used at the Landsburg Hatchery in 2006.

Spawning Week	Type Of Female	No. Of 3's	No. Of 4's	No. Of 5's	No. Of 6's	Totals By Type	Total Females	% Hatchery
17 - 23 Sep	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
24 - 30 Sep	NOR	1	44	3	0	48		
	Hatch	0	50	3	1	54	102	52.94%
1 - 7 Oct	NOR	0	31	4	0	35		
	Hatch	0	55	2	0	57	92	61.96%
8 - 14 Oct	NOR	0	60	7	0	67		
	Hatch	0	81	2	0	83	150	55.33%
15 - 21 Oct	NOR	0	67	13	0	80		
	Hatch	0	64	5	0	69	149	46.31%
22 - 28 Oct	NOR	0	107	11	0	118		
	Hatch	0	125	7	0	132	250	52.80%
29 Oct - 4 Nov	NOR	0	113	15	0	128		
	Hatch	0	175	8	0	183	311	58.84%
5 - 11 Nov	NOR	0	26	4	0	30		
	Hatch	0	37	1	0	38	68	55.88%
12 - 18 Nov	NOR	0	8	1	0	9		
	Hatch	0	13	2	0	15	24	62.50%
19 - 25 Nov	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
26 Nov - 2 Dec	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
3 - 9 Dec	NOR	-	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-	-
TOTALS		1	1056	88	1	1146		55.06%
Summary	NOR	1	456	58	0			515
	Hatch	0	600	30	1			631
	Totals	1	1056	88	1			1146

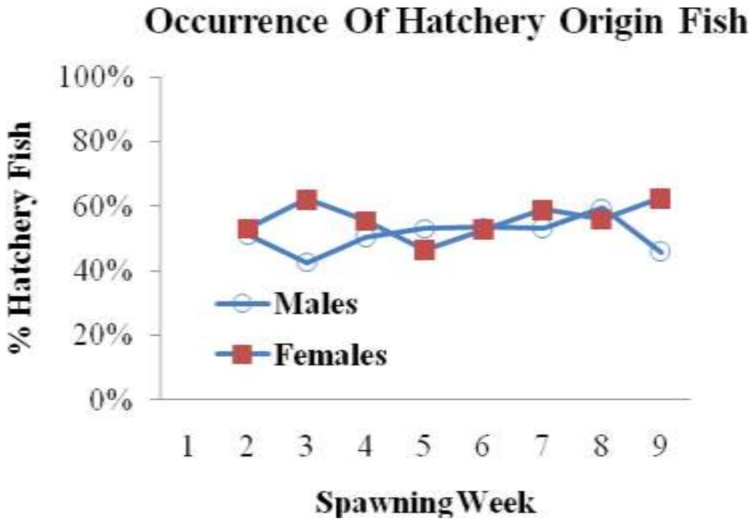


Figure 1. The percentage of hatchery origin males and females in the sockeye broodstock spawned at the Landsburg Hatchery in 2006 by spawning week.

compared the effect of release time on size at maturation in 5-yr-old males and females. Because relatively few 5-yr-old fish had been sampled we pooled data from adults that had originated from fed, unfed controls, and unfed fry releases. Time of release as a fry did not appear to influence body size at maturation in either 5-yr-old hatchery males (P = 0.265) or females (P = 0.693).

Six additional analyses were performed to examine the effect of fry type on size at maturation when age and gender were held constant (Table 7). The first two examined whether 4-yr-old males or females originating from fed and unfed fry used in the feeding experiment had different body sizes at maturation. No difference in POH lengths at maturation were detected in males (P = 0.679; or females (P = 0.618) that had been released as fed or unfed fry. ANOVAs were also used to determine if NOR and hatchery origin 4-yr-old sockeye males or females had different POH lengths at maturity. In these two analyses significant differences were observed. In males, adults originating from NOR and early unfed fry were larger than fish produced from unfed fry released during the middle and late periods. For females, adults created from fed and NOR fry were larger than those originating from middle and late unfed fry. The last two ANOVAs examined whether the POH lengths of 5-yr-old males and females were affected by their origin. These ANOVAs showed that NOR adult males (P < 0.001; 15.9 mm difference in mean size) and NOR females (P = 0.001; 16.2 mm difference in mean size) were significantly larger than adults produced from hatchery origin fish (*see* Table 5A and 5B).

Age At Maturation

Time of release (early, middle, and late) did not affect age of maturation in 4- and 5-yr-old hatchery origin males and females (Table 8). However, the 2x2 contingency Chi-Squares used to evaluate whether the age composition of NOR and hatchery sockeye used as broodstock differed indicated that in both sexes there was a higher incidence of 4-yr-olds and a decreased occurrence of 5-yr-olds in hatchery origin fish (Table 9). Although significant, these differences were

Table 5A. Mean POH lengths obtained from hatchery and NOR sockeye sampled at the Landsburg Hatchery in 2006.

Type Of Male	Release Type	Rearing Type	Age	n	Mean POH	Stdev
Hatchery	Early	Control	4	29	448.4	20.6
	Middle	Control	4	2	453.0	9.9
	Late	Control	4	9	448.0	27.3
	Overall	Control	4	40	448.6	21.5
Hatchery	Early	Fed	4	39	454.5	19.9
	Middle	Fed	4	16	449.8	21.9
	Late	Fed	4	25	444.0	22.8
	Overall	Fed	4	80	450.3	21.5
Hatchery	Early	Unfed	4	144	451.2	22.1
	Middle	Unfed	4	179	442.8	22.8
	Late	Unfed	4	113	444.5	20.1
	Overall	Unfed	4	436	446.0	22.2
Mean for Hatchery 4's			4	556	446.8	22.0
NOR	NA	NA	4	476	448.0	20.7
Hatchery	Early	Control	5	2	453.5	14.8
	Middle	Control	5	3	460.3	44.6
	Late	Control	5	4	470.0	14.5
	Overall	Control	5	9	463.1	25.6
Hatchery	Early	Fed	5	6	482.2	30.9
	Middle	Fed	5	1	470.0	-
	Late	Fed	5	0	-	-
	Overall	Fed	5	7	480.4	28.6
Hatchery	Early	Unfed	5	11	477.7	15.8
	Middle	Unfed	5	9	464.9	8.9
	Late	Unfed	5	3	467.7	29.9
	Overall	Unfed	5	23	471.4	16.2
Mean for Hatchery 5's				39	471.1	21.2
NOR	NA	NA		73	487.0	18.2

Table 5B. Mean POH lengths obtained from hatchery and NOR female sockeye sampled at the Landsburg Hatchery in 2006.

Type Of Female	Release Type	Rearing Type	Age	n	Mean POH	Stdev
Hatchery	Early	Control	4	35	437.3	22.1
	Middle	Control	4	0	-	-
	Late	Control	4	13	433.3	21.6
	Overall	Control	4	48	436.2	21.6
Hatchery	Early	Fed	4	47	439.0	18.6
	Middle	Fed	4	19	434.4	15.9
	Late	Fed	4	26	438.7	18.7
	Overall	Fed	4	92	437.9	18.0
Hatchery	Early	Unfed	4	199	435.3	21.7
	Middle	Unfed	4	169	430.0	20.0
	Late	Unfed	4	92	431.0	17.9
	Overall	Unfed	4	460	432.5	20.5
Mean for Hatchery 4's			4	600	433.6	20.3
NOR	NA	NA	4	456	437.8	21.3
Hatchery	Early	Control	5	0	-	-
	Middle	Control	5	1	455.0	-
	Late	Control	5	2	465.5	36.1
	Overall	Control	5	3	462.0	26.2
Hatchery	Early	Fed	5	7	455.6	24.4
	Middle	Fed	5	3	475.3	29.8
	Late	Fed	5	0	-	-
	Overall	Fed	5	10	461.5	26.2
Hatchery	Early	Unfed	5	9	461.0	28.8
	Middle	Unfed	5	7	460.6	17.2
	Late	Unfed	5	1	480.0	-
	Overall	Unfed	5	17	461.9	23.4
Mean for Hatchery 5's			5	30	461.8	23.7
NOR	NA	NA	5	58	478.0	20.0

Table 6. Results of the ANOVAs used to determine if release time affected size at maturity in hatchery origin sockeye sampled at the Landsburg Hatchery in 2006.

Null Hypothesis Tested	Gender	Age	N	*P* value	Results
Time of release did not affect size at maturation in the sockeye used as unfed controls in the	Male	4	40	0.957	Fail to Reject H_o
feeding experiment	Female	4	48	0.580	Fail to Reject H_o
Time of release did not affect size at maturation in the sockeye used as fed fish in the feeding	Male	4	80	0.157	Fail to Reject H_o
experiment	Female	4	92	0.628	Fail to Reject H_o
Time of release did not affect size at maturation in sockeye that were released as unfed fry but	Male	4	436	0.002	Reject H_o, Early > Middle & Late
not used in the feeding experiment	Female	4	460	0.033	Reject Ho, Early & Late Late & Middle
Time of release did not affect the size of 5-yr-old hatchery origin fish. Data from all the 5 yr-old	Male	5	39	0.265	Fail to Reject H_o
fish were pooled due to small samples sizes within each rearing group	Female	5	30	0.693	Fail to Reject H_o

Table 7. Results of the ANOVAs used to determine if fry type influenced size at maturation in 4- and 5-yr-old sockeye salmon sampled at the Landsburg Hatchery in 2006

Null Hypothesis Tested	Sex	Age	n	*P*-Value	Results Of ANOVAs
Hatchery adults produced from fed and control fry had similar lengths at maturity	Male	4	120	0.679	Fail to reject H_o
Hatchery adults produced from fed and control fry had similar lengths at maturity	Female	4	140	0.618	Fail to reject H_o
Hatchery (control, fed, & unfed) and NOR sockeye have similar lengths at maturity	Male	4	103 2	0.016	Reject H_o; Early Unfeds, NORs, Fed Fry, Controls Fed Fry, Controls, Middle & Late Unfeds
Hatchery (control, fed, & unfed) and NOR sockeye have similar lengths at maturity	Female	4	105 5	<0.001	Reject H_o; Fed Fry, NORs, Controls, Early Unfeds Controls, Early Unfeds, Middle & Late Unfeds
Hatchery (control, fed, & unfed) and NOR sockeye have similar lengths at maturity	Male	5	112	<0.001	Reject H_o; NORs > Fed Fry, Controls, Unfeds
Hatchery (control, fed, & unfed) and NOR sockeye have similar lengths at maturity	Female	5	89	0.001	Reject H_o; NORs > Fed Fry, Controls, Unfeds

Table 8. Results of the Chi-Square tests that evaluated the influence of date of release (early, middle, and late) on age at maturation in hatchery origin sockeye.

Null Hypothesis Tested	Gender	Age	v	Chi-Square Value	Conclusion
Time of release had no affect on age of maturation in hatchery fry					
Release groups were early, middle & late	Male	4	2	0.204	P = 0.903, Fail to reject H_o
Release groups were early, middle & late	Male	5	2	1.917	P = 0.384, Fail to reject H_o
Release groups were early, middle & late	Female	4	2	0.128	P = 0.938, Fail to reject H_o
Release groups were early, middle & late	Female	5	2	2.271	P = 0.321, Fail to reject H_o

Table 9. Results of the 2 x 2 contingency Chi-Square tests that compared age of maturation in NOR and hatchery-origin sockeye used as broodstock in 2006. Comparisons were made between fish having the same gender.

Null Hypothesis Tested	Sex	Age	v	Chi-Square Value	Conclusion
The incidence of 4-yr-old fish is the same in hatchery and NOR male Cedar River sockeye	Male	4	1	11.729	*P* = <0.001, 92.9% of the hatchery males were 4-yr-olds while 86.7% of the NOR males matured at age 4. Reject H_o
The incidence of 4-yr-old fish is the same in hatchery and NOR female Cedar River sockeye	Female	4	1	15.912	*P* = <0.001, 95.1% of the hatchery females were 4-yr-olds while 88.5% of the NOR females matured at age 4. Reject H_o
The incidence of 5-yr-old fish is the same in hatchery and NOR male Cedar River sockeye	Male	5	1	14.074	*P* = <0.001, 6.52% of the hatchery males were 5-yr-olds while 13.27% of the NOR males matured at age 5. Reject H_o
The incidence of 5-yr-old fish is the same in hatchery and NOR female Cedar River sockeye	Female	5	1	16.035	*P* = < 0.001, 4.75% of the hatchery females were 5-yr-olds while 11.26% of the NOR females matured at age 5. Reject H_o

relatively small. For example 93% of the hatchery males were 4-yr-olds while 86.7 of the NORs were this age amounting to a 6.25% difference in the prevalence of 4-yr-old males between hatchery and NOR fish. Similarly, there was a 6.6% difference between hatchery and NOR females in the occurrence of 4-yr-old females. Ninety-five percent of the hatchery females were 4's while 88.5% of the NOR females were this age. Comparable differences were observed in 5-yr-olds; in this case there was a 6.8% greater incidence of 5 yr-old NOR males and a 6.5% higher occurrence of 5-yr-old NOR females (see Tables 3 & 9). Once more information is gathered it may be possible to compare the age composition of hatchery and NORs by broodyear. This type of analysis will allow us to determine if allocation of fish into different age classes within a broodyear varies because of parental origin.

Release Type And Maturation Timing In Hatchery Origin Sockeye

As previously mentioned, when a hatchery fry is released is directly linked to the maturation timing of its parents because spring water with a relatively constant temperature is used for incubation at the Landsburg Hatchery. Kolmogorov-Smirnov tests showed that fish that were produced from early maturing parents matured earlier in the spawning season than those originating from parents who had been spawned during the middle and late periods of the spawning season. Differences were also detected in the maturation timing of fish that had been produced from parents who had matured during the middle and late spawning periods. Fish whose parents had been spawned in the middle of the spawning season at the hatchery became ripe or mature sooner than those whose parents had been artificially spawned at the end of the spawning season. Furthermore, males and females that were released as fry during the same time period became sexually mature at the same time. These results clearly indicate that when an adult is spawned or reaches sexual maturity will affect when its offspring spawn or reach sexual maturity. Table 10 summarizes the results of the Kolmogorov-Smirnov tests that were performed while Figure 2 illustrates some of the cumulative frequency comparisons that were made.

Fecundity And Relative Fecundity In Hatchery And NOR Females

Fecundity In Hatchery And NOR Females

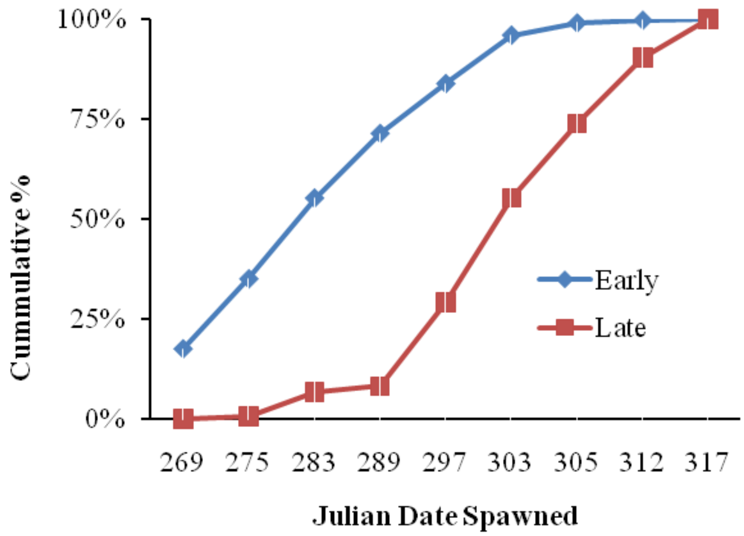
The regressions that examined the relationship between female weight and fecundity in 4- and 5-yr-old hatchery and NOR females were all significant. They indicated that female weight and egg number were positively related and that about 40 to 50% of the variation in fecundity could be explained by body weight (Table 11). The slopes and y-intercepts of the fecundity regressions performed on 4- and 5-yr-old hatchery females were found to be similar ($P = 0.710$ for slopes and $P = 0.969$ for y-intercepts). An analysis that compared the slopes and y-intercepts of the fecundity regressions performed on NOR females produced similar results (P for similar slopes equaled 0.300 and the P for the y-intercepts equaled 0.625). Thus, data from 4- and 5-yr-old females that were the same type (i.e. were of either hatchery or NOR origin) were pooled. The slopes and y-intercepts of these two combined fecundity regressions were also compared. No difference in the slopes ($P = 0.801$) or y-intercepts ($P = 0.889$) was found making it possible to pool all the fecundity data collected into a single regression formula. This overall relationship showed that 52% of the variation associated with fecundity in the females used as broodstock at Landsburg in 2006 could be explained by body weight.

A fixed factor two-way ANOVA was performed to examine the importance of female age (4 or

Table 10. Results of the Kolmogorov-Smirnov tests used to assess the effect of fry release timing (parental maturation date) on maturation timing in sockeye originating from the Landsburg Hatchery

Null Hypothesis Tested	Sex	Fry Release Time	n	D-Max Value	Conclusion
There is no difference in the maturation timing (spawning dates) of 4- & 5-yr-old fish produced from parents that were artificially spawned during the late and early portions of the spawning season	Male	Early Late	231 154	0.57	Reject H_o; $P < 0.001$. Males produced from adults who were spawned in the early part of the run matured sooner than those whose parents had been spawned in the late part of the run
	Female	Early Late	297 134	0.63	Reject H_o; $P < 0.001$. Females produced from adults who were spawned in the early part of the run matured sooner than those whose parents had been spawned in the late part of the run
There is no difference in the maturation timing (spawning dates) of 4- & 5-yr-old fish produced from parents that were artificially spawned during the middle and late portions of the spawning season	Male	Middle Late	210 154	0.29	Reject H_o; $P < 0.001$. Males produced from adults who were spawned in the middle part of the run matured sooner than those whose parents had been spawned in the late part of the run
	Female	Middle Late	199 134	0.24	Reject H_o; $P < 0.001$. Females produced from adults who were spawned in the middle part of the run matured sooner than those whose parents had been spawned in the late part of the run
Gender does not affect maturation timing in adults produced by parents that were spawned during the same time period	Male Female	Early Early	231 297	0.05	Fail to reject H_o; $P > 0.05$
	Male Female	Middle Middle	210 199	0.13	Fail to reject H_o; $P > 0.05$
	Male Female	Late Late	154 134	0.07	Fail to reject H_o; $P > 0.05$

A: Maturation timing in Hatchery Female Sockeye Salmon



B: Maturation Timing Of Early Male & Female Hatchery Sockeye Salmon

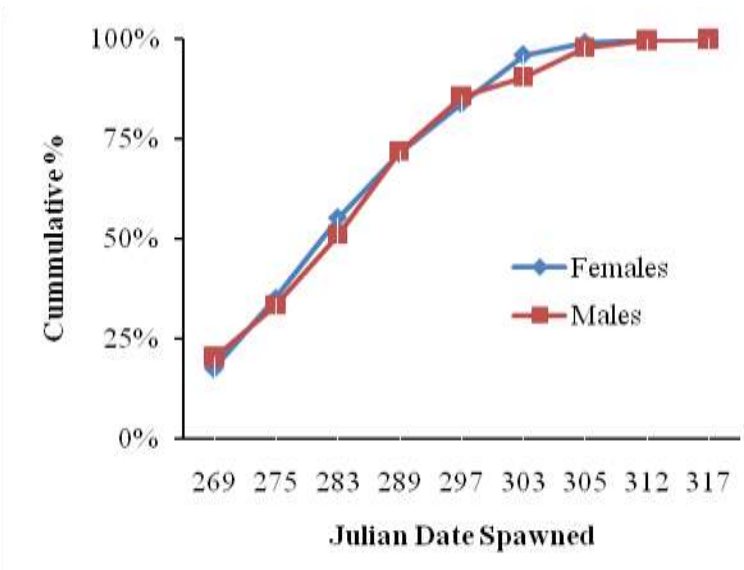


Figure 2. Cumulative frequencies that compare the maturation timing of adult females released as fry during the early and late periods (Part A). Gender effects on maturation timing in males and females released during the early period is shown in Part B.

5) and origin (NOR or hatchery) on mean fecundity. Five-yr-old females had greater mean fecundities than four-yr-olds (3,998 vs. 3,272 or a 726 egg difference). Female origin however, did not affect mean fecundity (P = 0.545) nor was there a significant interaction between female type and age (P = 0.478) on fecundity. There was for example, only a 23 egg difference in the mean fecundities of 4-yr-old NOR (3,287) and hatchery females (3,264) while in 5-yr-olds it

Table 11. Results of the linear regression analyses used to examine the relationship between female body weight (ln) and fecundity (ln) in 4- and 5-yr-old NOR and hatchery origin sockeye sampled in 2006 at the Landsburg Hatchery.

Regression Independent vs. Dependent Variable	Female Origin	Age	n	r^2	P value	Conclusion
Ln weight vs. Ln Fecundity	Hatchery	4	88	0.495	<0.001	Reject H_o, there was a positive relationship between female wt and fecundity
Ln weight vs. Ln Fecundity	NOR	4	49	0.386	<0.001	Reject H_o, there was a positive relationship between female wt and fecundity
Ln weight vs. Ln Fecundity	Hatchery	5	8	0.492	0.052	Reject H_o, there was a positive relationship between female wt and fecundity
Ln weight vs. Ln Fecundity	NOR	5	7	0.874	0.002	Reject H_o, there was a positive relationship between female wt and fecundity
Ln weight vs. Ln Fecundity	NOR & Hatchery	4 & 5	152	0.520	<0.001	Reject H_o, there was a positive relationship between female wt and fecundity

was just 29 eggs as the mean fecundity of NORs was 3,982 while in hatchery origin fish it equaled 4,011. Therefore the relationship between body weight and fecundity as well as mean fecundity in hatchery and NOR females maturing at the same age appears to be quite similar.

Relative Fecundity

Linear regression was used to examine the relationship between relative fecundity (eggs produced per kilogram of body weight) and female weight in 4- and 5-yr-old hatchery and NOR females. Often there is a weak but negative relationship between female weight and relative fecundity. However, in 2006 none of the regressions were significant indicating that there was no detectable relationship between female weight and the number of eggs produced per kilogram of body weight. A fixed factor two-way ANOVA was performed to see if origin (NOR and hatchery) or age (4 and 5) affected relative fecundity. In this analysis, neither origin (*P* = 0.142) nor age (*P* = 0.115) influenced relative fecundity. Also there was no interaction between age and origin on relative fecundity (*P* = 0.605). Consequently, NOR and hatchery origin females not only appear to have similar fecundities but also similar relative fecundity values (Table 12).

Table 12. Mean fecundity and relative fecundity in 4- and 5-yr-old NOR and hatchery origin sockeye used as broodstock at the Landsburg Hatchery in 2006.

Female Origin	Age	n	Mean Fecundity	Stdev Of Fecundity	Mean Relative Fecundity	Stdev Of Relative Fecundity
Hatchery	4	88	3264	515	1908.5	227.3
NOR	4	49	3287	566	1852.6	259.5
Hatchery	5	8	4011	761	1846.9	274.6
NOR	5	7	3982	649	1711.5	115.0

Egg Weights In 4- And 5-yr-old NOR And Hatchery Origin Females

Salmonid females typically exhibit a positive relationship between body weight and egg weight. Regression analyses were used to determine if linear relationships existed between these two parameters in the 4- and 5-yr-old NOR and hatchery origin females that were sampled at the Landsburg Hatchery in 2006. Just one of the four analyses run was significant (*P* = 0.022) and in this case only 11% of the variation in egg weight in 4-yr-old NOR females could be explained by body weight. A fixed factor two-way ANOVA disclosed that female origin (NOR & hatchery; *P* = 0.138), and age (4- or 5 yr-olds; *P* = 0.279) did not affect mean egg weight. Nor was there a significant interaction between age and origin on mean egg weight (*P* = 0.446). Thus in 2006 mean egg weights in all the females used as broodstock were similar to one another regardless of age at maturation or origin (Table 13).

Table 13. Mean water hardened egg weights in the 4- and 5-yr-old NOR and hatchery origin sockeye sampled at the Landsburg Hatchery in 2006.

Female Origin	Age	n	Mean Egg Wt (mg)	Stdev	Coefficient Of Variation
Hatchery	4	100	105.8	9.9	9.33%
NOR	4	59	107.8	11.5	10.67%
Hatchery	5	8	106.7	10.7	10.02%
NOR	5	7	113.0	7.2	6.33%

Reproductive Effort In Hatchery And NOR Females

The two-way ANOVA used to assess the importance of female age (4 or 5) and origin (NOR or hatchery) on reproductive effort disclosed that neither of these factors (age P = 0.201; origin P = 0.638) or an interaction between them (P = 0.940) affected this variable. In general, all the females, regardless of their age at maturation or their origin had reproductive effort values that averaged around 20%.

Table 14. Mean reproductive effort values (RE) in hatchery and NOR sockeye females maturing at ages 4 and 5 that were sampled at the Landsburg Hatchery in 2006.

Female Origin	Age	n	Mean RE %	Stdev	Coefficient of Variation
Hatchery	4	88	20.15%	1.77%	8.79%
NOR	4	49	19.89%	1.73%	8.70%
Hatchery	5	8	19.51%	2.13%	10.93%
NOR	5	7	19.30%	1.05%	5.45%

Results & Discussion: 2007

Occurrence Of Hatchery Fish In The Broodstock

In 2007, 40% of the sockeye used as broodstock at the Landsburg Hatchery were of hatchery origin (Table 15). This proportion of hatchery fish in the broodstock falls within the guidelines recently proposed by the HSRG. Almost all the sockeye (~95%) returning to the Cedar River in 2007 originated from the 2002 broodyear. In 2004 when these fish entered Lake Washington as fry, approximately 34% of them were of hatchery origin. If fry-to-adult survival rates in hatchery and NOR origin fish were equivalent, and a representative sample had been taken for broodstock then 34% of the broodstock should have been of hatchery origin. For reasons already given, we speculate that the weir location and when it was fished may have favored the collection of hatchery origin fish. Even if this bias exits, it is clear that hatchery origin fish produced large numbers of 5-yr-old adults and these fish made important contributions to the Cedar River hatchery program as well as to the natural spawning population.

Table 15. The occurrence of hatchery origin sockeye in the broodstock used at the Landsburg Hatchery from 1996 through 2007.

	% Of Broodstock Composed Of Hatchery Fish By Return Year											
Return Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
% Hatchery Fish	4%	12%	35%	45%	46%	38%	60%	54%	32%	33%	54%	40%

Out of the 1,664 sockeye spawned in 2007 at the Landsburg, 632 (317 females and 315 males) were sampled over a nine week spawning period. As Table 16 illustrates, 38% of the fish used as broodstock in 2007 were sampled. The origin and age of the fish sampled is shown in Table 17. As before, the column labeled "% Within A Type" indicates the percentage of fish that were of hatchery or NOR origin that were a given age. For example, 97.6% of all the hatchery males sampled were 5-yr-old fish. The column titled "% Within A Sex" indicates the percentage of all males, regardless of their origin that were a particular age. For instance, in 2007, 95.2% of the males sampled were 5-yr-old fish.

In 2007, sockeye were spawned over a nine-week period beginning during the week of 24 – 30 September and ending in the week of 19-25 November. No formal analyses were performed to see if the percentage of hatchery fish used as broodstock changed over the course of the spawning season. However, Tables 18 A and 18 B and Figure 3 show that these percentages varied from 30 to 60% in males and from 24 to 48% in females. No temporal trend in hatchery fish abundance appeared to occur.

Length Comparisons Between Hatchery And NOR Sockeye Used As Broodstock

Table 19 parts A and B summarize the POH data collected on broodstock sampled at the hatchery. Because so few 4- and 3-yr-old fish were sampled our comparisons of POH lengths were restricted to hatchery and NOR fish that matured at age 5. Six ANOVAs were performed. The first two compared the POH lengths of adults that had been produced from releases of unfed fry that were not part a feeding experiment that occurred at the hatchery in 2003 (Table 20). The analysis performed on males showed that individuals originating from unfed fry released during the early period (POH = 504 mm) had greater mean POH lengths (P = 0.006) than those produced by unfed fry released during the late period (POH = 488 mm). However, no difference in POH lengths (P = 0.399) was found between adults released during the early (POH = 504 mm) and middle periods (POH = 497 mm) and the POH lengths of males released during the middle (POH = 497 mm) and late time periods (POH = 488) were also similar (P = 0.161). No difference was seen in the POH lengths of females that had been released as unfed fry during the early (POH = 486 mm), middle (POH = 485 mm) or late (POH = 482 mm) periods (P = 0.671).

Table 16. The number of male and female sockeye spawned and sampled per week at the Landsburg Hatchery from September through December 2007.

Spawning Week	No. Of Females	No. Of Males	Total Fish Spawned	Total Fish Sampled	% Sampled By Week	Females Sampled	% By Week	Males Sampled	% By Week
17 - 23 Sep	0	0	0	0	0	0	0	0	0
24 - 30 Sep	39	39	78	0	0	0	0	0	0
1 - 7 Oct	118	118	236	120	50.85%	60	50.85%	60	50.85%
8 - 14 Oct	196	196	392	120	30.61%	60	30.61%	60	30.61%
15 - 21 Oct	108	108	216	76	35.19%	38	35.19%	38	35.19%
22 - 28 Oct	94	94	188	80	42.55%	40	42.55%	40	42.55%
29 Oct - 4 Nov	132	132	264	82	31.06%	42	31.82%	40	30.30%
5 - 11 Nov	85	85	170	80	47.06%	40	47.06%	40	47.06%
12 - 18 Nov	42	42	84	40	47.62%	20	47.62%	20	47.62%
19 - 25 Nov	18	18	36	34	94.44%	17	94.44%	17	94.44%
26 Nov - 2 Dec	0	0	0	0	0.00%	0	0	0	0
3 - 9 Dec	0	0	0	0	0.00%	0	0	0	0
Totals	832	832	1664	632	37.98%	317	38.10%	315	37.86%

Table 17. The origin, sex, and ages of the sockeye salmon that were sampled at the Landsburg Hatchery in 2007

Type	Age	n	% Within A Type	% Within A Sex
Hatchery Male	3	3	2.38%	0.95%
	4	0	0.00%	3.81%
	5	123	97.62%	95.24%
Subtotal		126		
NOR Male	3	0	0.00%	0.95%
	4	12	6.35%	3.81%
	5	177	93.65%	95.24%
Subtotal		189		
Grand Total		315		
Hatchery Female	3	2	1.57%	0.63%
	4	0	0.00%	2.84%
	5	125	98.43%	96.53%
Subtotal		127		
NOR Female	3	0	0.00%	0.63%
	4	9	4.74%	2.84%
	5	181	95.26%	96.53%
Subtotal		190		
Grand Total		317		

Definitions: % Within a Sex = percentage of fish that were a given age within a fish type (e.g. NORs or Hatch) and gender

% Within a Sex = percentage of fish that were a given age within the same gender (combined NOR and Hatch data)

Table 18 A. The occurrence of 3-, 4-, and 5-yr-old NOR and hatchery origin sockeye males by spawning week in the broodstock used at the Landsburg Hatchery in 2007

Spawning Week	Type Of Male	No. Of 3's	No. Of 4's	No. Of 5's	Totals By Type	Total Males	% Hatchery
17 - 23 Sep	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
24 - 30 Sep	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
1 - 7 Oct	NOR	0	2	39	41		
	Hatch	0	0	19	19	60	31.67%
8 - 14 Oct	NOR	0	0	39	39		
	Hatch	0	0	21	21	60	35.00%
15 - 21 Oct	NOR	0	1	21	22		
	Hatch	0	0	16	16	38	42.11%
22 - 28 Oct	NOR	0	0	22	22		
	Hatch	1	0	17	18	40	45.00%
29 Oct - 4 Nov	NOR	0	3	22	25		
	Hatch	1	0	14	15	40	37.50%
5 - 11 Nov	NOR	0	2	13	15		
	Hatch	1	0	24	25	40	62.50%
12 - 18 Nov	NOR	0	2	12	14		
	Hatch	0	0	6	6	20	30.00%
19 - 25 Nov	NOR	0	2	9	11		
	Hatch	0	0	6	6	17	35.29%
26 Nov - 2 Dec	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
3 - 9 Dec	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
TOTALS		3	12	300	315		40.00%
Summary	NOR	0	12	177			189
	Hatch	3	0	123			126
	Totals	3	12	300			315

Table 18 B. The occurrence of 3-, 4-, and 5-yr-old NOR and hatchery origin sockeye females by spawning week in the broodstock used at the Landsburg Hatchery in 2007.

Spawning Week	Type Of Female	No. Of 3's	No. Of 4's	No. Of 5's	Totals By Type	Total Females	% Hatchery
17 - 23 Sep	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
24 - 30 Sep	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
1 - 7 Oct	NOR	0	2	35	37		
	Hatch	0	0	23	23	60	38.33%
8 - 14 Oct	NOR	0	0	31	31		
	Hatch	0	0	29	29	60	48.33%
15 - 21 Oct	NOR	0	0	20	20		
	Hatch	0	0	18	18	38	47.37%
22 - 28 Oct	NOR	0	2	19	21		
	Hatch	0	0	19	19	40	47.50%
29 Oct - 4 Nov	NOR	0	0	29	29		
	Hatch	0	0	13	13	42	30.95%
5 - 11 Nov	NOR	0	0	27	27		
	Hatch	1	0	12	13	40	32.50%
12 - 18 Nov	NOR	0	3	9	12		
	Hatch	1	0	7	8	20	40.00%
19 - 25 Nov	NOR	0	2	11	13		
	Hatch	0	0	4	4	17	23.53%
26 Nov - 2 Dec	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
3 - 9 Dec	NOR	-	-	-	-	-	-
	Hatch	-	-	-	-	-	-
TOTALS		2	9	306	317		40.06%
Summary	NOR	0	9	181		190	
	Hatch	2	0	125		127	
	Totals	2	9	306		317	

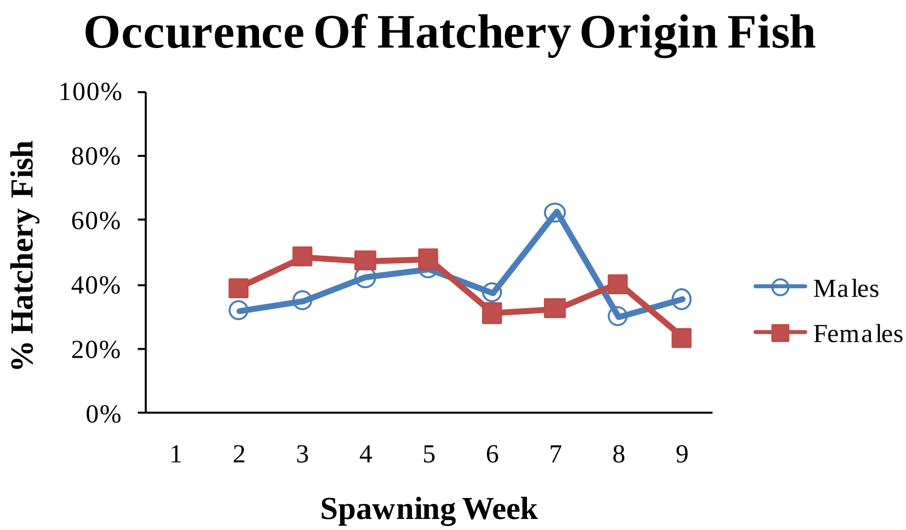


Figure 3. The percentage of hatchery origin males and females in the sockeye broodstock spawned at the Landsburg Hatchery in 2007 by spawning week.

Too few fish originating from the feeding experiment were sampled to allow the affect of release time on POH lengths to be evaluated within a sex (male or female) and fry release type (fed or unfed). Instead POH values were pooled by type of fry within the same sex and ANOVAs were performed to see if POH lengths at maturity had been affected by whether a fry had been released as a fed or unfed fry. No differences were seen, P = 0.730 for the males (fed POH = 485 mm and unfed POH = 482 mm) and P = 0.655 for females (fed POH = 479 mm and unfed POH = 484 mm). Two final ANOVAs were performed to ascertain whether the POH lengths of hatchery and NOR fish differed from one another. In the ANOVA that compared male lengths, data from three types of males, NORs, males produced from unfed early release fry, and males produced from all the other hatchery fry types were compared. Five-yr-old males produced from early unfed fry were significantly larger than NORs (P = 0.036; early unfed POH = 504 vs. NOR POH = 493 mm) and from males produced by the other hatchery release groups (P = 0.010; early unfed POH = 504 mm vs. remaining hatchery males POH = 490 mm). The ANOVA that compared the POH values of hatchery origin and NOR females was not significant (P = 0.154; hatchery female POH = 484 mm; NOR female POH = 488 mm).

Age At Maturation

Time of release (early, middle, and late) did not affect age of maturation in 5-yr-old hatchery origin males and females (Table 22). Furthermore, the 2 x 2 contingency Chi-Square tests used to evaluate whether the age composition of NOR and hatchery sockeye used as broodstock were comparable indicated that there were no differences in their age composition (Table 23). For example, in hatchery fish, 97.6% of the males and 98.4% of the females were 5-yr-olds while in NORs, 93.6 % of the males and 95.3% of the females were 5's. This meant that there was just a 4% difference in the occurrence of 5-yr-old males and a 3% difference in the incidence of 5-yr-old females. Typically, Lake Washington sockeye reach maturation at age 4. The scarcity of 4-yr-old NORs and hatchery fish in 2007 suggests that a biological catastrophe occurred to the

Table 19 A. Mean POH lengths obtained from hatchery and NOR male sockeye sampled at the Landsburg Hatchery in 2007.

Type Of Male	Release Type	Rearing Type	Age	n	Mean POH	Stdev
Hatchery	Early	Control	4	-	-	-
	Middle	Control	4	-	-	-
	Late	Control	4	-	-	-
	Overall	Control	4	-	-	-
Hatchery	Early	Fed	4	-	-	-
	Middle	Fed	4	-	-	-
	Late	Fed	4	-	-	-
	Overall	Fed	4	-	-	-
Hatchery	Early	Unfed	4	-	-	-
	Middle	Unfed	4	-	-	-
	Late	Unfed	4	-	-	-
	Overall	Unfed	4	-	-	-
Mean for Hatchery 4's			4	-	-	-
NOR	NA	NA	4	12	456.4	49.9
Hatchery	Early	Control	5	7	481.0	24.2
	Middle	Control	5	3	486.0	16.5
	Late	Control	5	5	482.0	17.3
	Overall	Control	5	15	482.3	19.5
Hatchery	Early	Fed	5	5	490.6	27.2
	Middle	Fed	5	2	497.0	25.5
	Late	Fed	5	5	475.4	25.0
	Overall	Fed	5	12	485.3	25.3
Hatchery	Early	Unfed	5	31	503.6	18.7
	Middle	Unfed	5	32	497.1	17.5
	Late	Unfed	5	33	488.0	22.7
	Overall	Unfed	5	96	496.1	20.6
Mean for Hatchery 5's				123	493.3	21.4
NOR	NA	NA		177	492.7	24.0

Table 19 B. Mean POH lengths obtained from hatchery and NOR female sockeye sampled at the Landsburg Hatchery in 2007.

Type Of Female	Release Type	Rearing Type	Age	n	Mean POH	Stdev
Hatchery	Early	Control	4	-	-	-
	Middle	Control	4	-	-	-
	Late	Control	4	-	-	-
	Overall	Control	4	-	-	-
Hatchery	Early	Fed	4	-	-	-
	Middle	Fed	4	-	-	-
	Late	Fed	4	-	-	-
	Overall	Fed	4	-	-	-
Hatchery	Early	Unfed	4	-	-	-
	Middle	Unfed	4	-	-	-
	Late	Unfed	4	-	-	-
	Overall	Unfed	4	-	-	-
Mean for Hatchery 4's			4	-	-	-
NOR	NA	NA	4	9	445.3	30.0
Hatchery	Early	Control	5	6	477.5	27.8
	Middle	Control	5	1	509.0	-
	Late	Control	5	7	486.1	17.1
	Overall	Control	5	14	484.1	22.4
Hatchery	Early	Fed	5	2	517.5	20.5
	Middle	Fed	5	3	458.0	40.7
	Late	Fed	5	7	477.6	20.3
	Overall	Fed	5	12	479.3	30.9
Hatchery	Early	Unfed	5	29	486.2	22.3
	Middle	Unfed	5	40	485.1	19.0
	Late	Unfed	5	30	481.9	16.9
	Overall	Unfed	5	99	484.5	19.3
Mean for Hatchery 5's			5	125	483.9	20.9
NOR	NA	NA	5	181	487.7	24.2

Table 20. Results of ANOVAs used to determine if release time affect size at maturity in hatchery origin sockeye.

Null Hypothesis Tested	Gender	Age	N	*P* value	Conclusion
Time of release did not affect size at maturation in sockeye that were released as unfed fry but not used in the feeding experiment	Male	5	96	0.009	Reject H_o, <u>Early , Middle</u> <u>Middle, Late</u>
	Female	5	99	0.671	Fail to reject H_o

Table 21. Results of ANOVAs that evaluated whether: 1) fed and unfed fry released as part of a feeding experiment had different POH values at maturity, and 2) hatchery and NOR sockeye had similar lengths at maturity.

Null Hypothesis Tested	Gender	Age	n	*P* value	Conclusion
Hatchery adults produced from fed and control fry had similar lengths at maturity	Male	5	27	0.730	Fail to reject H_o
	Female	5	26	0.655	Fail to reject H_o
Hatchery and NOR sockeye have similar POH lengths at maturity	Male	5	300	0.015	Reject H_o <u>Early Unfed Hatchery</u> > <u>NOR, Combined Hatchery</u>
	Female	5	306	0.154	Fail to reject H_o

Table 22. Results of the Chi-Square tests that evaluated the influence of release period (early, middle, and late) on age at maturation in hatchery origin sockeye.

Null Hypothesis Tested	Gender	Age	v	Chi-Square Value	Conclusion
Time of release had no affect on age of maturation in unfed hatchery fry					
Release groups were early, middle & late	Male	5	2	0.056	Fail to reject H_o
Release groups were early, middle & late	Female	5	2	0.017	Fail to reject H_o

Table 23. Results of the Chi-Square tests that compared age at maturation in NOR and hatchery origin fish having the same gender.

Null Hypothesis Tested	Gender	Age	v	Chi-Square Value	Conclusion
The incidence of 5-yr-old fish is the same in hatchery and NOR male Cedar River sockeye	Male	5	2	1.475	Fail to reject H_o
The incidence of 5-yr-old fish is the same in hatchery and NOR fe male Cedar River sockeye	Female	5	2	0.505	Fail to reject H_o

2003 broodyear. What the eventual fry-to-adult survival rates amount to in these fish will have to wait until we collect age and abundance information on sockeye returning to the Lake Washington basin in 2008 and 2009. However, based on the number of sockeye returning to Lake Washington in 2008, survival of fish produced from this broodyear is likely to be extremely low.

Release Type And Maturation Timing In Hatchery Origin Sockeye

As mentioned earlier, when a hatchery fry is released is directly linked to the maturation timing of its parents because spring water with a relatively constant temperature is used for incubation at the Landsburg Hatchery. Thus, adults spawned during the early part of a spawning season produce fry that are released during the early part of the fry release period, and so on. The thermal codes induced into the otoliths of all hatchery fish make it possible to determine when a fish was released, as different codes are used to designate early, middle, and late release times. Kolmogorov-Smirnov tests were performed to ascertain if fish produced from parents spawned occurring during the early, middle, and late periods of a spawning season reached maturation at the same time as their parents. These tests showed that there was a strong connection between when a hatchery fish reached maturation or became ripe, and when during a spawning season its parents had been spawned. Adults produced from parental fish that matured during the first part of a spawning season, for example, were also the first fish to mature and be spawned in their spawning season. Additionally, males and females that were released as fry during the same time period became sexually mature at the same time. Table 24 summarizes the results of the Kolmogorov-Smirnov tests performed while Figure 4 illustrates some of the cumulative frequency comparisons that were made.

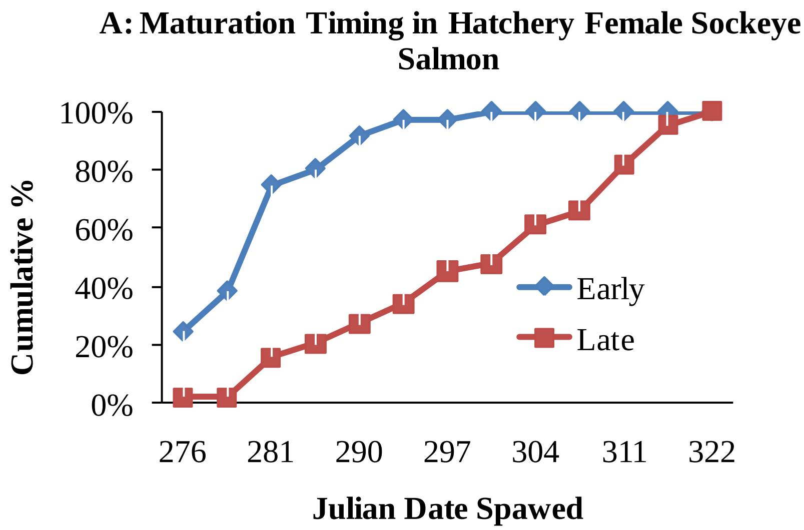
Fecundity And Relative Fecundity In Hatchery And NOR Females

<u>Fecundity In Hatchery And NOR Females</u>

The regressions that examined the relationship between female weight and fecundity in 5-yr-old hatchery and NOR females were significant (Table 25). Female body weight explained 41% (in hatchery) and 46% (in NORs) of the variation in fecundity. Fecundity information was also obtained from five, 4-yr-old NOR females. In this case the regression was not significant, mainly due to the small sample size. The slopes and y-intercepts of the two NOR regressions were found to be similar (P = 0.322 for slopes and P = 0.983 for y-intercepts) so a single NOR equation was generated and it explained approximately 52% of the variation in egg number by female weight. The slope and y-intercept of this equation was compared with those obtained from the 5-yr-old hatchery equation. Again no differences in slope (P = 0.977) or elevation were found (P = 0.940). Data from all the females were then combined to produce an overall equation that explained 47% of the variation in fecundity by female weight. Consequently, the relationship between female weight and fecundity was not affected by age or by origin. Mean fecundity values in 4- and 5-yr-old NOR females were compared by using a two-sample t-test and a significant difference was found (P = <0.001) as 5-yr-old NORs had on average 861 more eggs than 4-yr-old NORs. (P = 0.167). However, the mean fecundities of 5-yr-old hatchery and NOR females did not differ from one another (P = 0.167) indicating that the overall fecundity values of the two types of females were comparable as long as age was held constant.

Table 24. Results of the Kolmogorov-Smirnov tests used to assess the effect of fry release timing on maturation timing in hatchery sockeye returning to the Landsburg Hatchery.

Null Hypothesis Tested	Sex	Population	n	D-Max Value	Conclusion
There is no difference in the maturation timing (spawning dates) of 5 yr-old fish produced from parents that were artificially spawned during the early and late portions of the spawning season	Male	Early	43	0.63	Reject H_o, $P < 0.001$. Males produced from adults who were spawned early matured sooner than those whose parents were spawned later
		Late	43		
	Female	Early	36	0.64	Reject H_o, $P < 0.001$. Females produced from adults who were spawned early matured sooner than those whose parents were spawned later
		Late	44		
There is no difference in the maturation timing (spawning dates) of 5 yr-old fish produced from parents that were artificially spawned during the early and late portions of the spawning season	Male	Middle	37	0.32	Reject H_o, $P < 0.05 > 0.01$. Males produced from adults who were spawned in the middle period matured sooner than those whose parents were spawned in the late period
		Late	43		
	Female	Middle	44	0.34	Reject H_o, $P < 0.05 > 0.01$. Females produced from adults who were spawned in the middle period matured sooner than those whose parents were spawned in the late period
		Late	44		
Gender does not affect maturation timing in adults produced by parents that had similar spawning dates	Male	Early	43	0.17	Fail to reject H_o, $P > 0.05$
	Female	Early	36		
	Male	Middle	37	0.16	Fail to reject H_o, $P > 0.05$
	Female	Middle	44		
	Male	Late	43	0.18	Fail to reject H_o, $P > 0.05$
	Female	Late	44		



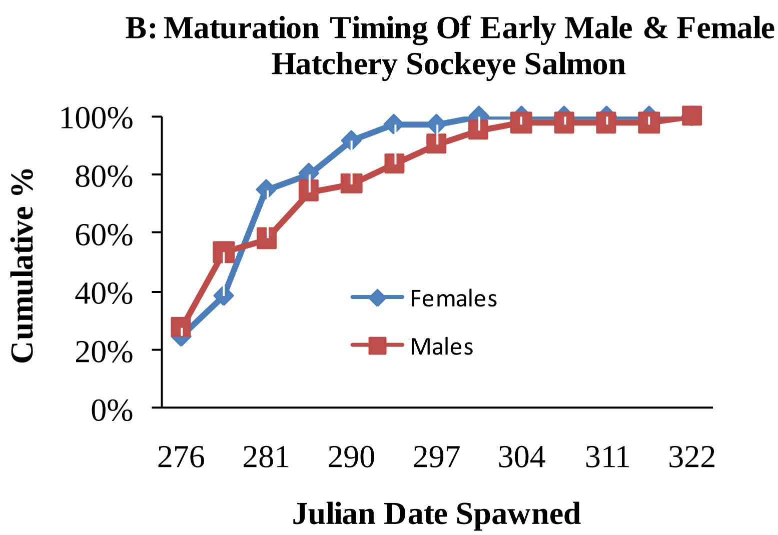


Figure 4. Cumulative frequencies that compare the maturation timing of adult females released as fry during the early and late periods (Part A). Gender effects on maturation timing in males and females released during the early period is shown in Part B.

Table 25. Results of the linear regression analyses used to examine the relationship between female weight (ln) and fecundity (ln) in 4- and 5-yr-old NOR and hatchery origin sockeye sampled at the Landsburg Hatchery in 2007.

Regression Independent vs. Dependent Variable	Female Origin	Age	n	r^2	P value	Conclusion
Ln weight vs. Ln Fecundity	Hatchery	4	-	-	-	NA no 4-yr-old hatchery females were sampled
Ln weight vs. Ln Fecundity	NOR	4	5	0.509	0.176	Fail to reject H_o
Ln weight vs. Ln Fecundity	Hatchery	5	80	0.409	<0.001	Reject H_o, a positive relationship between body wt. & fecundity was observed
Ln weight vs. Ln Fecundity	NOR	5	113	0.456	<0.001	Reject H_o, a positive relationship between body wt. & fecundity was observed
Ln weight vs. Ln Fecundity	NOR & Hatchery	4 & 5	198	0.473	<0.001	Reject H_o, a positive relationship between body wt. & fecundity was observed

Relative Fecundity

Linear regression was used to examine the relationship between relative fecundity (eggs produced per kilogram of body weight) and female weight in 5-yr-old NOR and hatchery females. These regressions were significant (*P* = <0.001) and both had negative slopes indicating that as body weight increased fewer eggs were produced per kilogram. The slopes and y-intercepts or elevations of the two regression lines were compared and no difference was detected (*P* = 0.977 for slopes and *P* = 0.933 for elevation). Thus, 5-yr-old hatchery and NOR females sampled at the hatchery appear to have similar relationships between relative fecundity and body weight. Results of a two-sample t-test used to determine if mean relative fecundity values of 5-yr-old NOR and hatchery females differed was also non-significant (*P* = 0.526). Consequently, not only did the 5-yr-old NOR and hatchery origin females sampled in 2007 have similar fecundities but they also had similar relative fecundities.

Table 26. Mean fecundity and relative fecundity in 4- and 5-yr-old NOR and hatchery origin sockeye used as broodstock at the Landsburg Hatchery in 2007.

Female Origin	Age	n	Mean Fecundity	Stdev Of Fecundity	Mean Relative Fecundity	Stdev Of Relative Fecundity
Hatchery	4	-	-	-	-	-
NOR	4	5	3294	599.6	1987	235.5
Hatchery	5	80	4043	550.2	1717	197.9
NOR	5	113	4155	554.3	1734	194.4

Egg Weights In 4- And 5-yr-old NOR And Hatchery Origin Females

Salmonid females typically exhibit a positive relationship between body weight and egg weight. Regression analyses that examined this relationship in 5-yr-old NOR and hatchery females were both significant, *P* < 0.001 and had positive slopes. In NOR females body weight could explain about 15% of the variation in egg weight while in hatchery females approximately 16% of the variation in egg weight could be explained by female weight. The slopes and elevations of the two regression were compared and found to be similar (*P* = 0.741 for slopes and *P* = 0.858 for y-intercepts or elevations). A one-way ANOVA was used to assess whether 4-yr-old NORs and 5-yr-old NORs and hatchery females possessed different mean egg weights. This analysis showed that both types of 5-yr-old females had heavier eggs than the 4-yr-old NORs (*P* = 0.003 for hatchery 5-yr-olds and *P* = 0.004 for 5-yr-old NORs). No difference was seen in the mean egg sizes of 5-yr-old hatchery and NOR females (*P* = 0.953). Thus in 2007, mean egg weight in hatchery and NOR females were similar as long as age was held constant (Table 27).

Table 27. Mean water hardened egg weights in the 3-, 4-, and 5-yr-old NOR and hatchery origin sockeye sampled at the Landsburg Hatchery in 2007.

Female Origin	Age	n	Mean Egg Wt (mg)	Stdev	Coefficient Of Variation
Hatchery	3	2	90.0	1.4	1.60%
NOR	3	-	-	-	-
Hatchery	4	-	-	-	-
NOR	4	7	98.0	8.8	9.00%
Hatchery	5	101	111.7	11.5	10.30%
NOR	5	147	111.2	10.9	9.80%

Reproductive Effort In Hatchery And NOR Females

The one-way ANOVA that compared the reproductive effort values of 4- and 5-yr-old NORs and 5-yr-old hatchery fish was non-significant ($P = 0.783$). Regardless of their origin the 4- and 5-yr-old females sampled in 2007 had reproductive effort values that averaged 19% (Table 28) and again no detectable difference was observed between hatchery and NOR females.

Table 28. Mean reproductive effort (RE) values in hatchery and NOR sockeye females maturing at ages 3, 4, and 5 that were sampled at the Landsburg Hatchery in 2007.

Female Origin	Age	n	Mean RE %	Stdev	Coefficient of Variation
Hatchery	3	2	17.47%	0.90%	5.26%
Hatchery	4	-	-	-	-
NOR	4	5	18.84%	1.03%	5.46%
Hatchery	5	79	19.12%	1.33%	6.94%
NOR	5	113	19.22%	1.48%	7.68%

Some Final Considerations For The Results Obtained In 2006 & 2007

A number of traits like body length, weight, egg weight, and fecundity are affected by how old a fish is at maturity. Therefore, our ability to compare traits like these in NOR and hatchery origin sockeye will be affected by our ability to assign correct ages to both NORs and hatchery fish. The ages of hatchery origin fish can be unambiguously assigned because the fish receive thermal marks that disclose their broodyear. Conversely, age estimates for NORs must be made by examining external banding patterns on the surface of their otoliths. We believe that hatchery fish can be used to estimate the accuracy of such assignments. This can be accomplished by comparing ages obtained from examining external banding patterns found on their otoliths to ages obtained by deciphering thermal marks. In 2006 we obtained 91% agreement between these two methods when they were used to age 4- and 5-yr-old fish. In 2007 we had 96% agreement between the ages produced by thermal marks and exterior otolith banding patterns. In 2007 only 5-yr-old hatchery fish were sampled, as no 4-yr-olds were recovered so for this year the 96% value represents the accuracy of our age estimates for 5-yr-olds.

In 2006, all the 5-yr-olds that were incorrectly aged were classified as 4-yr-olds. If a comparable error rate occurred in NORs then size data from true 5's would be included in the data sets for 4-yr-olds. Since 5's are usually larger than 4's this would tend to make NOR 4-yr-olds appear larger than they truly are. Similarly, all the incorrectly aged 4's were thought to be 5-yr-olds. The inclusion of size data of 4's thought to be 5's would tend to reduce the mean size of 5-yr-old NORs. To see how great an affect these errors might have, mean POH sizes were calculated for hatchery males and females using ages obtained from external otolith banding patterns. These lengths were then compared to those obtained by using thermal codes. Data presented in Table 29 indicate that mean POH values were not greatly affected by our errors in estimating age based on external banding patterns.

Consequently, we believe that any age assignment errors made on NORs in 2006 and 2007 had little impact on the trait comparisons that were made. Certainly, a very conservative approach would be to pay the greatest attention to comparisons made between NORs and hatchery fish that were at the predominate age of maturation in their return year. Our ability to accurately age these fish proved to be quite high. For example, in 2006 most of the sockeye returning to the Cedar River were age 4 when slightly over 90% of the fish matured at this age. In this year 94.4% of the 4-yr-old hatchery fish were aged correctly by examining external banding patterns present on their otoliths. And in 2007, the predominate age of return was 5 when 95.9% of the fish matured at this age. In this year 96% of the 5-yr-old hatchery fish were aged correctly by external banding patterns. Thus, any errors associated with missed aged assignments should have had minimal impacts on our comparisons between 4-yr-old fish in 2006 and 5-yr-old fish in 2007. This can be seen in Table 29. Notice that the difference between mean POH lengths in 4-yr-old fish in 2006 were a mm or less and in 2007 differences in POH lengths in 5-yr-old fish were between 0.2 mm in males and 1.3 mm in females.

The Landsburg Hatchery represents one of the few places where reproductive trait comparisons between NORs and hatchery origin fish are taking place. These comparisons are providing us with a way to discover if inadvertent domestication caused by exposure to salmon culture protocols is occurring in the Cedar River sockeye population. Data collected from these fish in 2005, 2006, and 2007 have indicated that NOR and hatchery origin fish appear to have similar reproductive traits. This may be because these traits have already been shifted by exposure to the hatchery prior to our detailed assessments or it may be that the hatchery program has had a light impact on the population. In either case, it will be worthwhile to continue to monitor these traits over time, particularly when the occurrence of hatchery origin fish in the broodstock is expected to increase due to recent low survival rates experienced by the population.

Table 29. Comparisons between the mean POH lengths of hatchery males and females derived from two ageing methods, thermal otolith codes and external banding patterns on the otolith surface.

2006: Source Of Age Estimate	Sex	Age	n	Mean POH Length	Stdev
Thermal Code	Male	4	556	446.8	22.0
External Otolith Banding Pattern	Male	4	547	445.8	21.4
Thermal Code	Male	5	39	471.1	21.2
External Otolith Banding Pattern	Male	5	48	477.8	15.7
Thermal Code	Female	4	600	433.6	20.3
External Otolith Banding Pattern	Female	4	607	433.7	20.1
Thermal Code	Female	5	30	461.8	23.7
External Otolith Banding Pattern	Female	5	23	468.2	25.6
2007: Source Of Age Estimate	**Sex**	**Age**	**n**	**Mean POH Length**	**Stdev**
Thermal Code	Male	4	0	-	-
External Otolith Banding Pattern	Male	4	2	486.5	38.9
Thermal Code	Male	5	123	493.3	21.4
External Otolith Banding Pattern	Male	5	121	493.5	21.3
Thermal Code	Female	4	0	-	-
External Otolith Banding Pattern	Female	4	6	459.5	25.9
Thermal Code	Female	5	125	483.9	20.9
External Otolith Banding Pattern	Female	5	119	485.2	19.9

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